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Title: Neutron Detector Based on Particles of 6Li Glass Scintillator Dispersed in Organic Light Guide Matrix

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Neutron Detector Based on Particles of ^{6}Li Glass Scintillator Dispersed in Organic Light Guide Matrix

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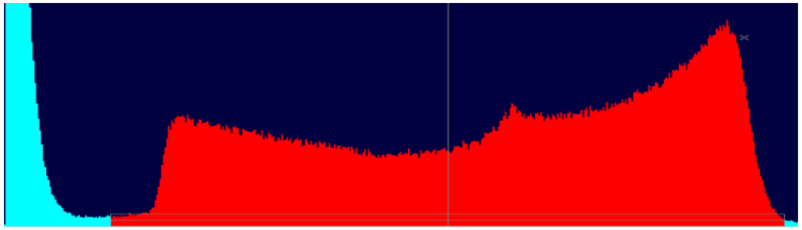
Introduction: Motivation For This Work

^{3}He, BF_3 tubes – life was easy



- Neutron and gamma distributions well separated:
  - Plateau in counting characteristic
  - Stability and gammas not critical
  - Easy to model (MCNP reaction rate equal to counting rate)
- Dead Time remains an issue

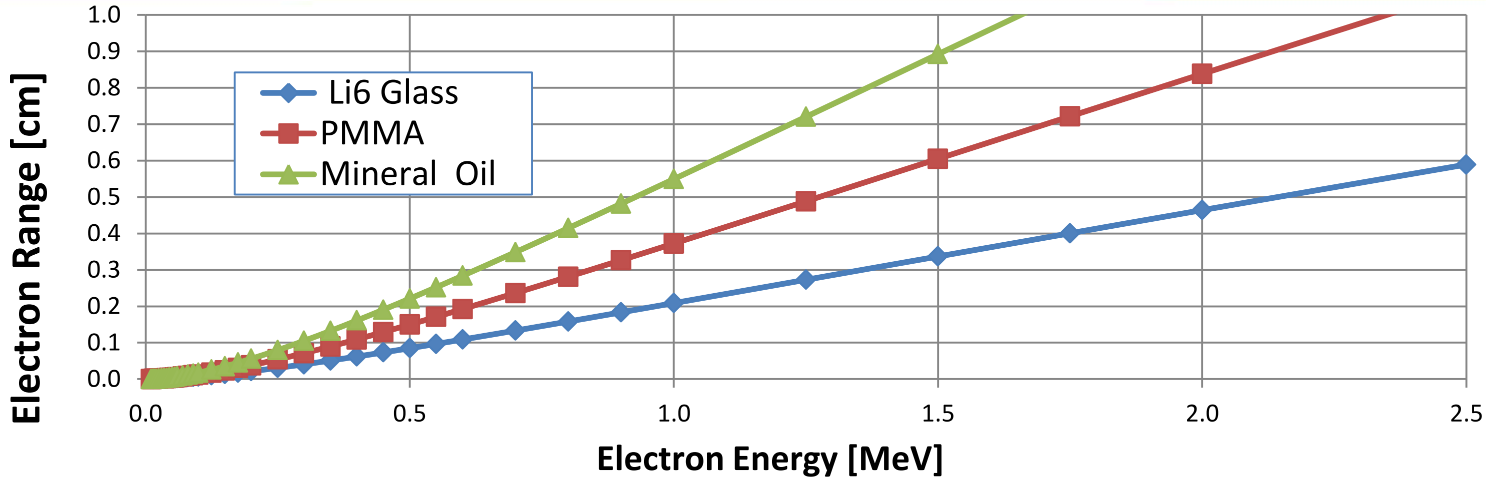
^{10}B, ^{6}Li alternatives – We are facing challenges

- Neutrons and gamma distributions overlap significantly:
  - Stability and event threshold setting become an issue
  - Difficult to model (reaction rate different from counting rate)
  - Easier to implement in Go-no-Go type systems as RPM
  - Much more difficult to implement in analytical instruments
  - Separated distributions critical for neutron multiplicity counting

Introduction: Distributed Li-6 Glass Neutron Detector

- ^{6}Li (Ce) glass scintillators could be attractive alternative for ^{3}He replacement:
  - Good light output (single peak about 1800 keVee , with FWHM less than 10%)
  - Good stopping power for thermal neutrons ~75% for 1 mm (GS20)
  - Chemically inert and easy to form in different shapes.
  - Short light decay time (about 50-60 ns)
  - But high gamma sensitivity has limited wide application as neutron detector
- **Different approaches for reduction of gamma sensitivity proposed and tested**:
  - L.M. Bollinger (early 60s) to embed Li-glass particles in organic lightguide medium
  - Nucsafe used thin glass fibers with non scintillation cladding, recently ^{6}Li glass microspheres

Distributed ^{6}Li Glass Neutron Detector How May It Work?

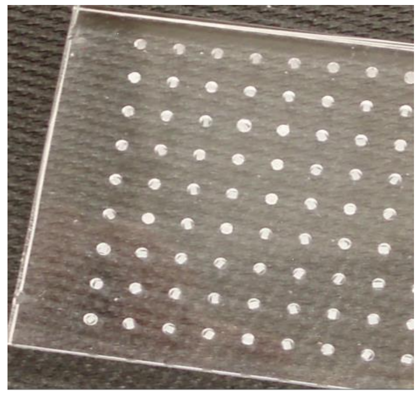


- **Li-6 glass particles size selection :**
  - **Maximum size limited by the maximum energy of gamma to be deposited**
  - **Minimum size limited by incomplete energy deposition from Li-6 particles**
- **Particles need to be surrounded by non scintillating lightguide material to absorb the excess of electrons energy (selection of distance between ^{6}Li glass particles).**
- **Matching of refraction indexes is critical for reduction of light losses**

2”by2”by2” Proof of Principle Prototype: Construction and Fabrication Process

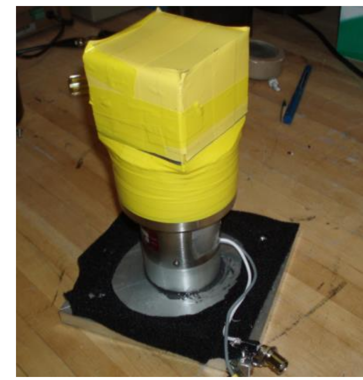
A

B



C

D



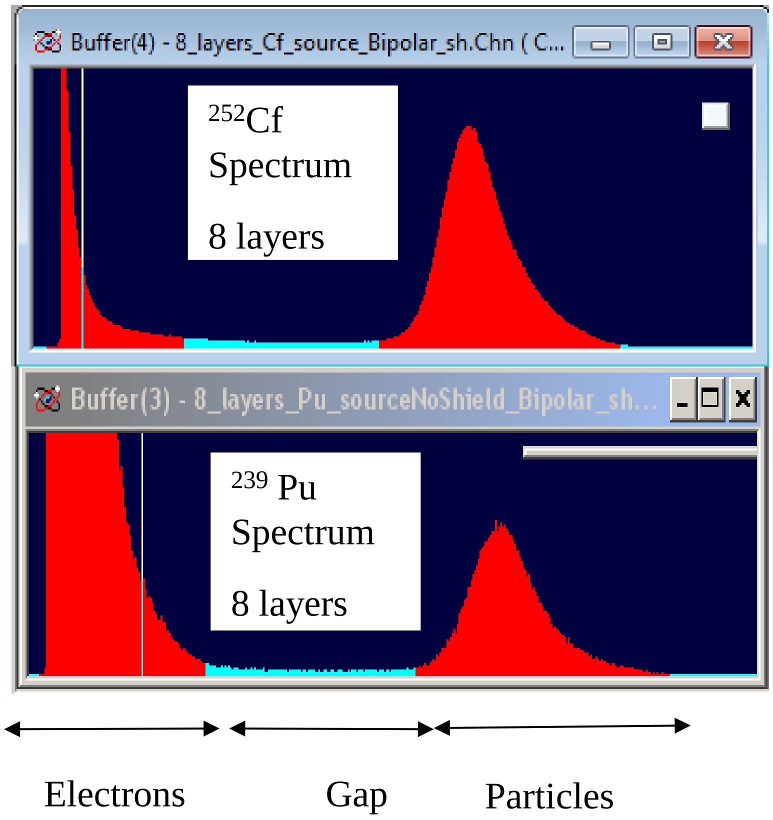
A. Unpolished 1 mm^2 150 mm long rods of GS20 cut into 1mm^3 cubes

B. Scintillator particles installed in dimples on 2”X2”X0.25” thick PMMA plate. Spacing 0.2”

C. Eight PMMA plates in 2”by2”by2” enclosure on the top of 3” PMT . Cavities filled with Castor oil

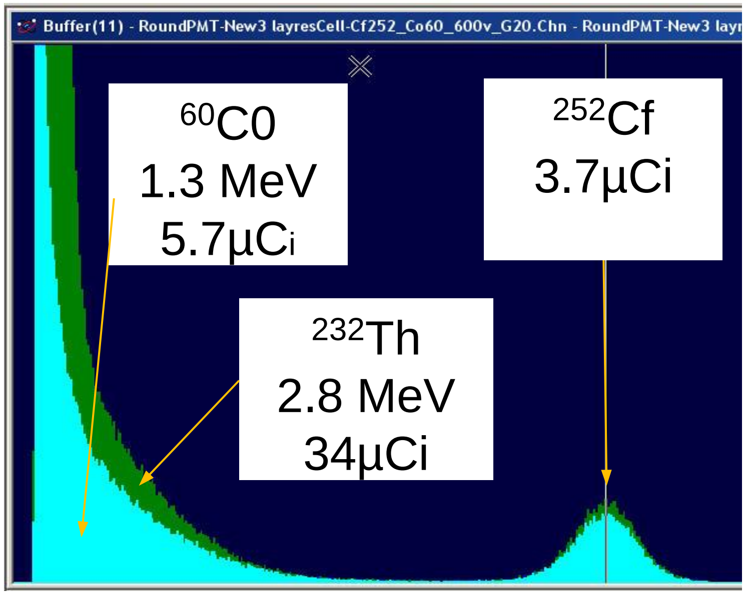
D. Detector mounted inside pipe enclosure

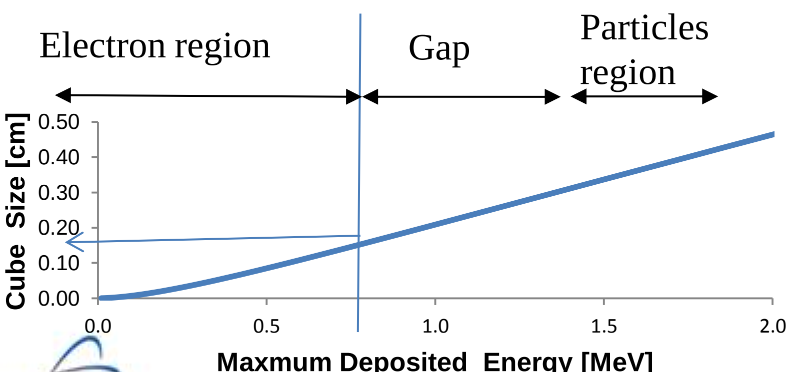
2”by2”by2” Proof of Principle Prototype ^{252}Cf and ^{239}Pu Pulse Height Distribution



- Wide gap between neutron and gamma response for both sources
- Asymmetry and shift of neutrons peak due to light losses
- More intensive gamma spectrum for ^{239}Pu
- Allows use of 1.5 mm particles in detectors for Pu measurements and eases scaling-up to bigger size:
  - Better light transport
  - Ease of manufacturing
  - Lower cost

2”by2”by2” Proof Of Principle Prototype ^{252}Cf And ^{60}Co And ^{232}Th Spectra





- Neutron capture peak about 1.6 MeV_{ee} and about 12% FWHM
- Gamma maximum pulse height limited by the size of the Li-glass particles
- Maximum energy corresponds to 1.7 mm main diagonal
- True gap between neutron and gamma distribution!

3” Dia. 10”Long Feasibility Study Prototype : Construction and Fabrication Process

A. Conceptual design of detector package (25 rods in 3” by 10” tube)

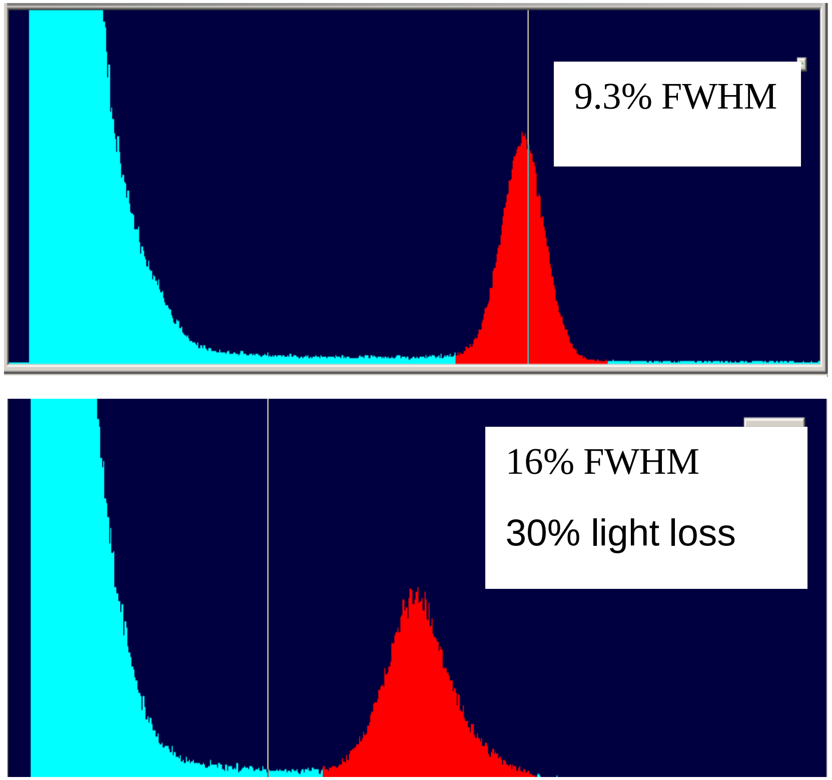
B. 10” long square rod with 1.5 mm GS20 cubes (200 cubes per rod)

C. Assembled detector on vertical stand (top PMT removable)

D. Top view of reference geometry (2 rods in 3” dia. tube filled with oil)

E. Top view of worse case geometry (2 rods in 0.75” dia. tube filled with oil)

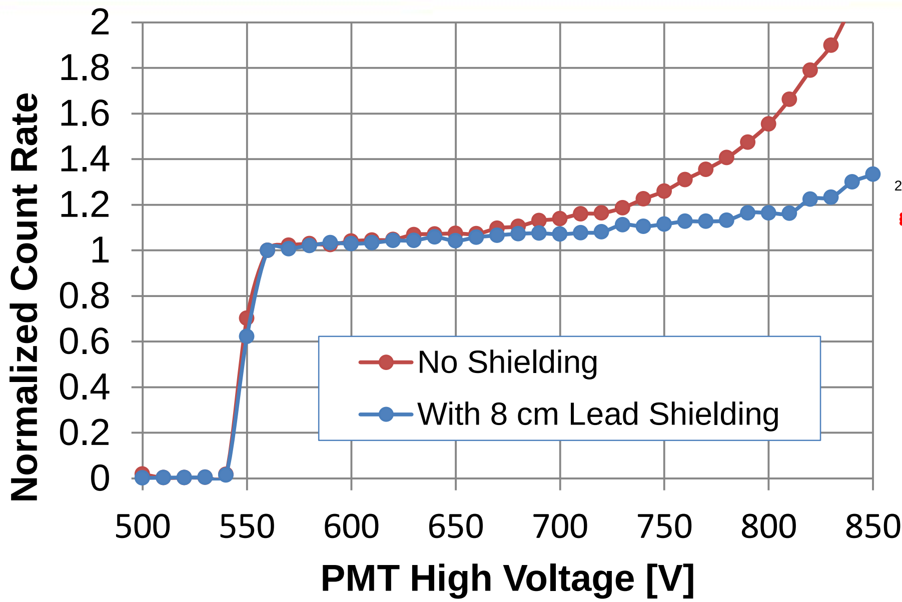
Feasibility Study Prototype
^{239}Pu Spectra for two Geometries

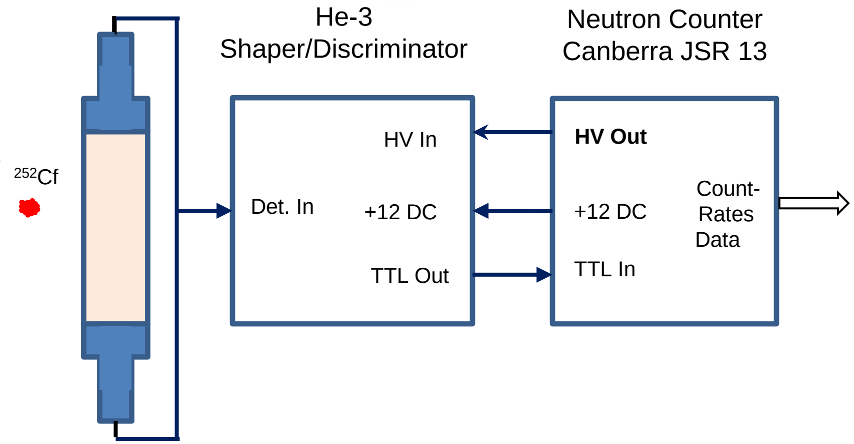


- Reference case light transport
  - 3” dia. 10”long
  - 0.2% by volume ^{6}Li glass.
  - Wide gap
- Worse case light transport
  - 0.75” dia. 10” long
  - 3% by volume ^{6}Li glass.
  - Preserved gap

Scaling to large size 4” dia. 20” long detectors feasible

Distributed ^{6}Li Glass Neutron Detector Plateau of Counting Characteristic





- True plateau with knee at 560V. Slope on the plateau is specific to particle size (easy to account for in MCNP)
- Simple ^{3}He like counting electronics
- But much faster (less than 100 ns Dead Time)

Possible Applications

- **Neutron well multiplicity counter:**
  - Reaction Rate Modeling of ^{6}Li foil based counter (NIM A ,662, v1): 133 grams Li-6 foil dispersed in 33 liter cavity shows 34% efficiency and 16 μs die-away time
  - Design using about 2000g of GS20 glass cubes would have same amount of Li-6 atoms, respectively similar efficiency; shorter die away time; gamma tolerance and no DT issues .
- **Active interrogation (DDA):**
  - Fast recovery from gamma splash
  - Very short die away time
  - Very high count rate capabilities (expected DT less than 100 ns)
- **Detectors Array for Imaging and fast neutrons energy**
- **Hand held detectors**

Acknowledgments

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Conclusions

- Li-6 glass particles detector concept and prototype have been presented.
- Initial experimental data demonstrate:
  - Full functional replacement of He-3 (BF_3) proportional counters: high efficiency; good neutron/gamma separation; simple electronics and much shorter dead time
  - Potential to outperform He-3 tubes for neutron well multiplicity counter
  - Application specific overall detector design
- Other applications and funding path forward to be explored